Measurement of the Spin Asymmetry in the Photoproduction of High-p_T Hadron Pairs

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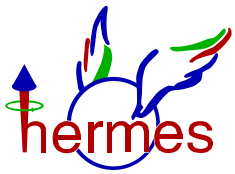

for the HERMES Collaboration

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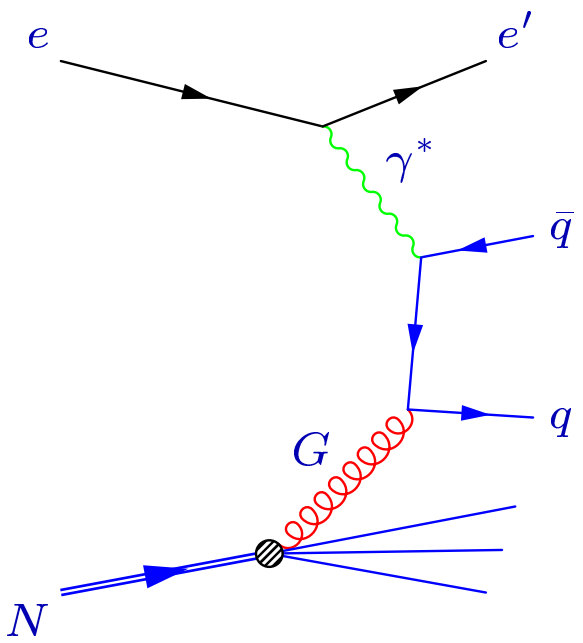
Outline

- Motivation
- Experiment
- Analysis
- Interpretation
- $\Delta G/G$

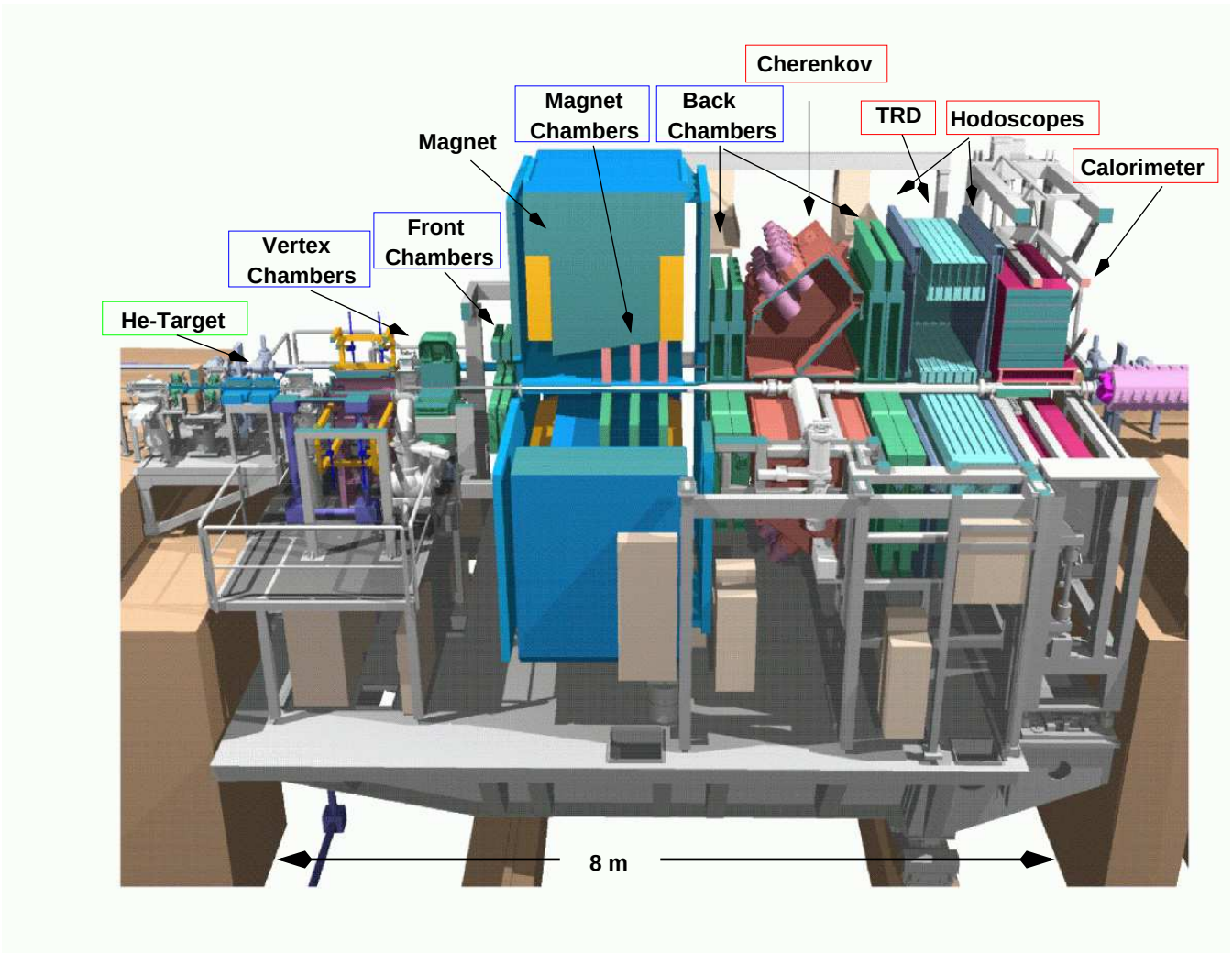
Goal

To isolate photon gluon fusion using kinematical cuts on hadrons, thereby providing a direct measurement of the gluon polarization in the nucleon, $\Delta G/G$.



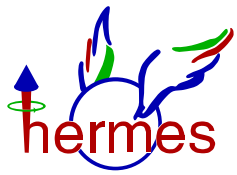
- PGF is isolated at collider experiments via $e + p \rightarrow e'$+ 2 jets + target fragments. (see e.g. H1, NPB**75**(1995)539 $G(x)$ from dijet production)
- HERMES does not have jets, can use high-p_T hadrons instead. (see e.g. study for COMPASS Bravar et al, Phys. Lett. B**421**(1998)349, study for SLAC E154, E155 Afanasev et al, Phys. Rev. D**58**(1998)054007)
- The cross-section is maximal at $Q^2 = 0$. Thus, include statistics from quasi-real photoproduction.

The HERMES Experiment



- Use HERA 27.5 GeV $\vec{e}$ ring. $P_{\mathrm{beam}} \approx 0.55$.
- Internal $^1\vec{\mathrm{H}}$ ABS target. $P_{\mathrm{target}} \approx 0.88$.
- Forward spectrometer (40 mrad $<$ $\theta_{\mathrm{lab.}}$ $<$ 220 mrad). momentum resolution $\delta p/p \approx 1\%$.
- PID accomplished using four detectors: calorimeter, preshower, TRD, threshold Č. Probability of e/h misidentification $\approx 0.2\%$.

Experimental Technique



Measure the cross section asymmetry:

$$A_{||} = \frac{d\sigma^{\uparrow\downarrow} - d\sigma^{\uparrow\uparrow}}{d\sigma^{\uparrow\downarrow} + d\sigma^{\uparrow\uparrow}} = \frac{N^- L^+ - N^+ L^-}{N^- L_P^+ + N^+ L_P^-}$$

- $N^+(N^-)$ = number of hadron pairs observed for target spin parallel (anti-parallel) to beam spin orientation.
- $L^\pm$ = integrated luminosity in each target spin state.
- $L_P^\pm$ = beam and target polarization weighted luminosity.

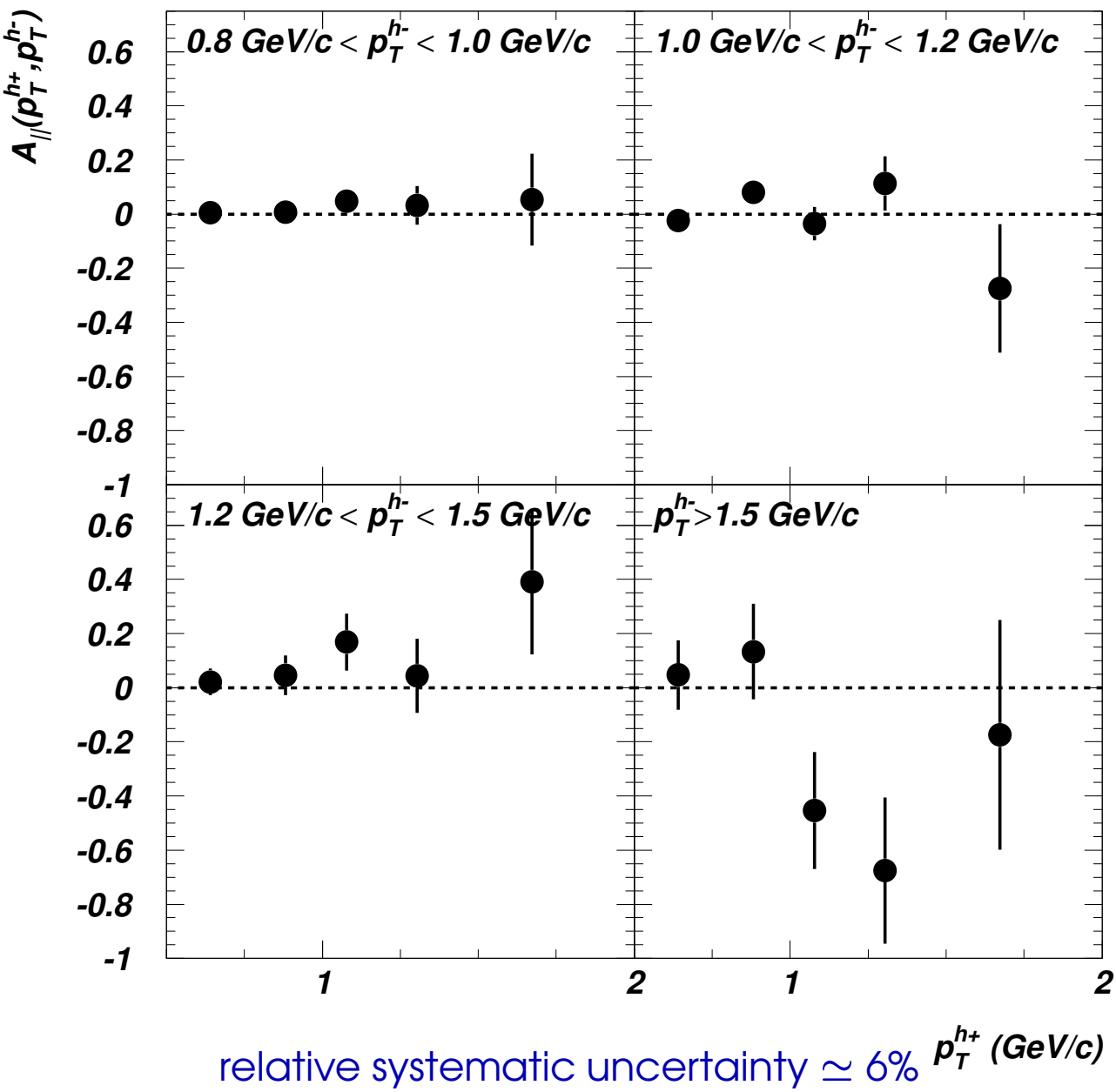
Data Selection:
Search for Photoproduced Hadron Pairs

Require:

- At least two hadrons of opposite charge in the event.
- No scattered positron in the event.
- The fastest two oppositely charged hadrons must have high momentum ($>$ 4.5 GeV/c) and high p_T ($>$ 0.5 GeV/c).
- $M(2\pi) > 1.0$ GeV/c^2, to reduce contributions ρ and ϕ mesons and VMD processes.

Bin data in $p_T^{h^+}$, $p_T^{h^-}$ and study variation.

Measured Asymmetry $A_{||}(p_T^{h^+}, p_T^{h^-})$

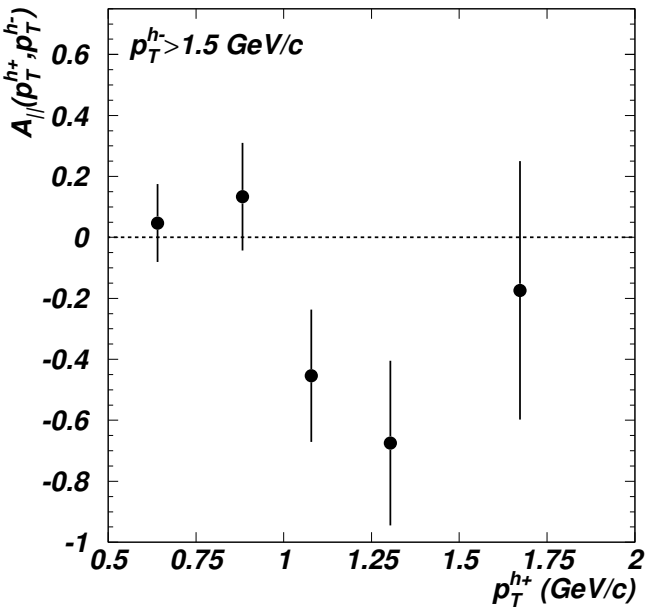


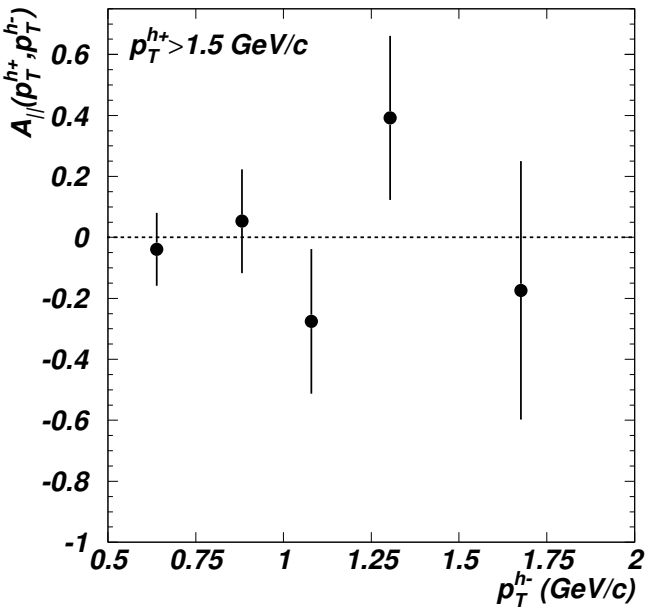
relative systematic uncertainty $\simeq$ 6%

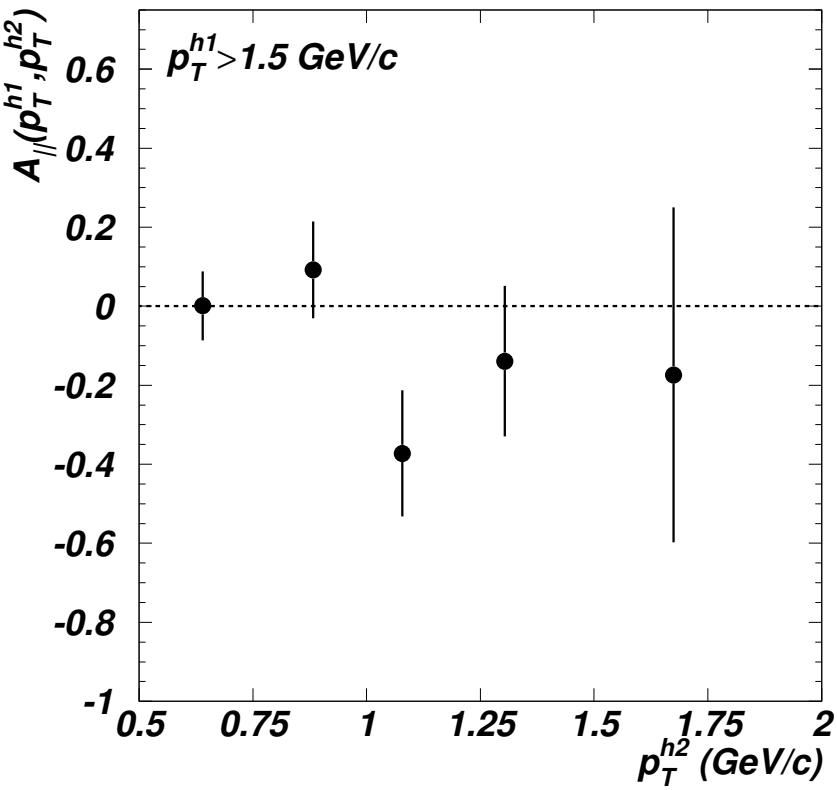
Checks that were performed on the data:

- ✔ stability of asymmetry and yield with time.
- ✔ consistent result obtained using identified pions only.
- ✔ $e^+ - h^+$ misidentification is negligible.
- ✔ independent analysis that uses different selection criteria.

Region of Interest





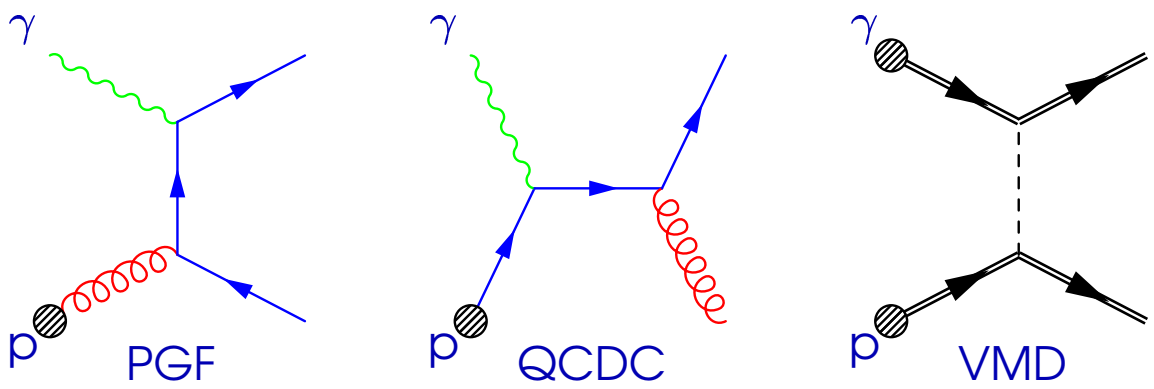


relative systematic uncertainty $\simeq$ 6%

PYTHIA gives more reliable description of events in this region.

Interpretation

Use PYTHIA Monte Carlo generator



$$A_{||} = A_{\rm PGF} f_{\rm PGF} + A_{\rm QCDC} f_{\rm QCDC} + A_{\rm VMD} f_{\rm VMD}$$
$$\simeq A_{\rm PGF} f_{\rm PGF} + A_{\rm QCDC} f_{\rm QCDC}$$

f_i is unpolarized fraction of events for subprocess i = QCDC, PGF, VMD. In small region of phase space take (in LO QCD):

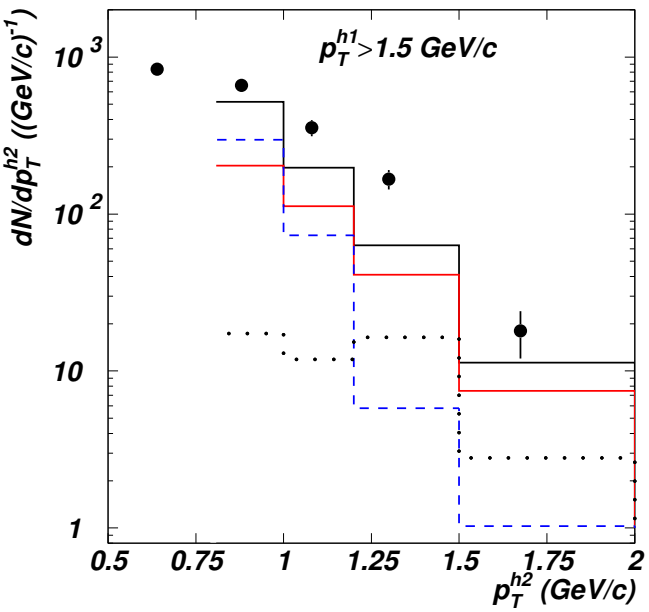
$$A_{\rm PGF} \simeq \langle \hat{a}(\gamma G \to q\bar{q}) \rangle \langle \frac{\Delta G}{G} \rangle = \langle \hat{a}_{\rm PGF} \rangle \frac{\Delta G}{G}$$
$$A_{\rm QCDC} \simeq \langle \hat{a}(\gamma q \to qG) \rangle \langle \frac{\Delta q}{q} \rangle = \langle \hat{a}_{\rm QCDC} \rangle \frac{\Delta q}{q}$$

$\hat{a}_{\rm PGF} = -1$ and $\hat{a}_{\rm QCDC} \simeq 0.5$ are subprocess asymmetries directly calculable in LO QCD.

Invert to extract $\Delta G/G$:

$$\frac{\Delta G}{G} \simeq \frac{A_{||} - \langle \hat{a}_{\rm QCDC} \rangle \frac{\Delta q}{q} f_{\rm QCDC} \langle D(y) \rangle}{\langle \hat{a}_{\rm PGF} \rangle f_{\rm PGF} \langle D(y) \rangle}$$

Cross Section Comparison



solid black = total,
dashed red = PGF,
dotted blue = QCDC,
dot-dashed black = soft VMD.

data are compared in a region where PYTHIA model is independent of $\hat{p}_T^{\min}$ cut-off parameter.

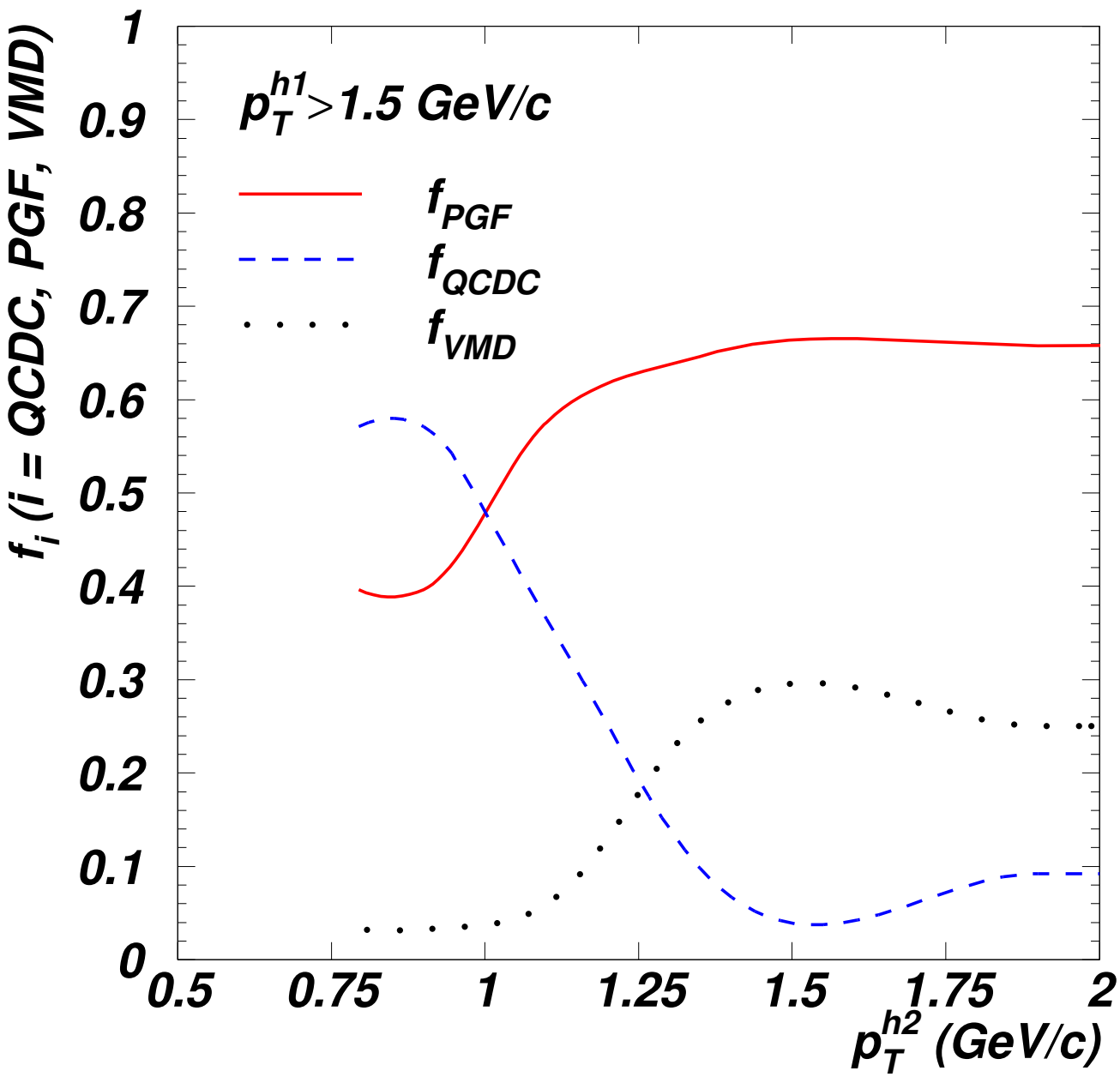
MC Low by Factor of Two!

Possible reasons:

- neglect of hard VMD/anomalous processes?
- neglect of NLO effects?
- fragmentation parameters need to be retuned?

Extracted subprocess fractions

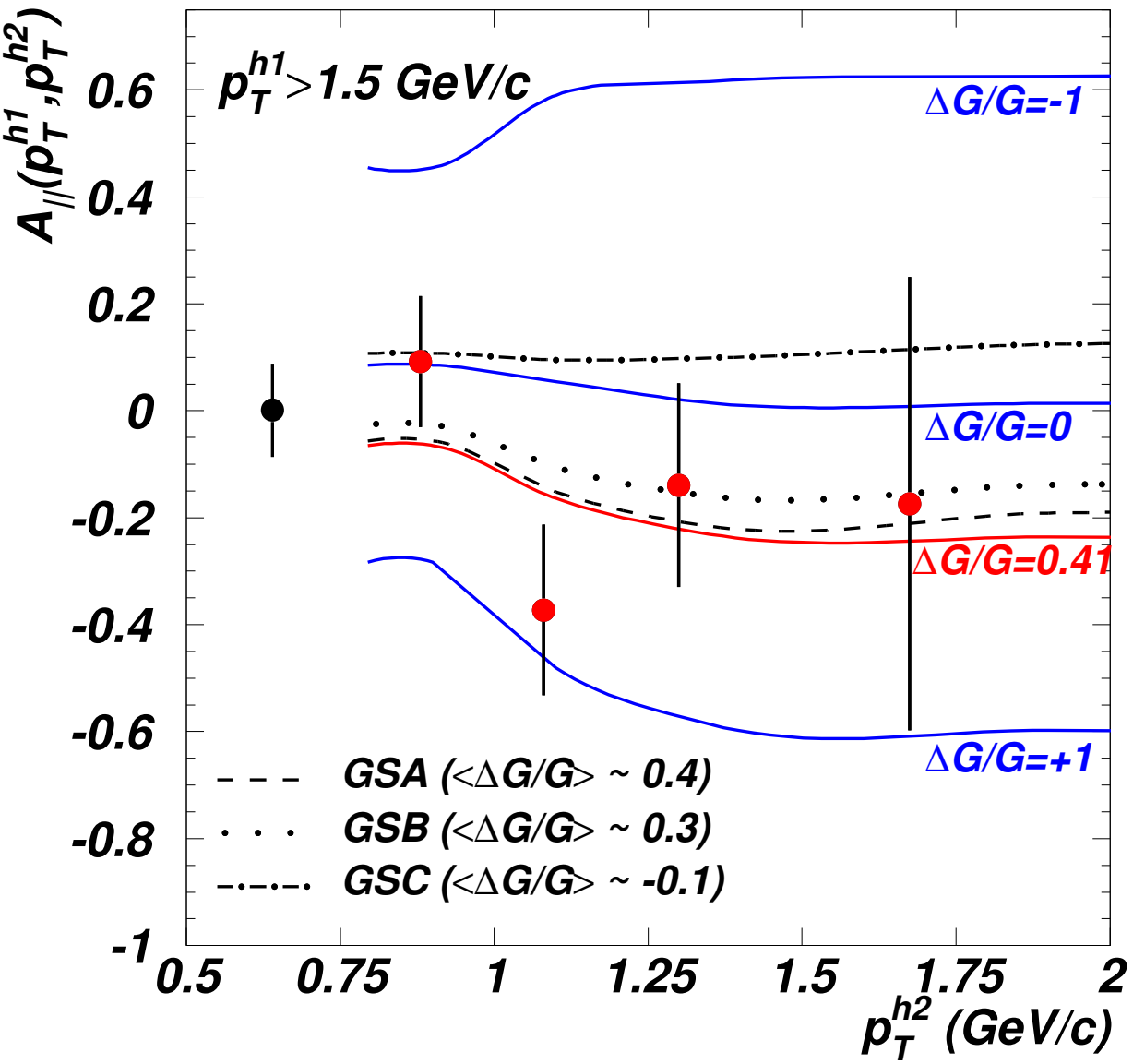
The negative asymmetry is observed where PGF is expected to dominate.



Result Using PYTHIA Model

$$\Delta G/G = 0.41 \pm 0.18\ (\text{stat.}) \pm 0.03\ (\text{exp. syst.})$$

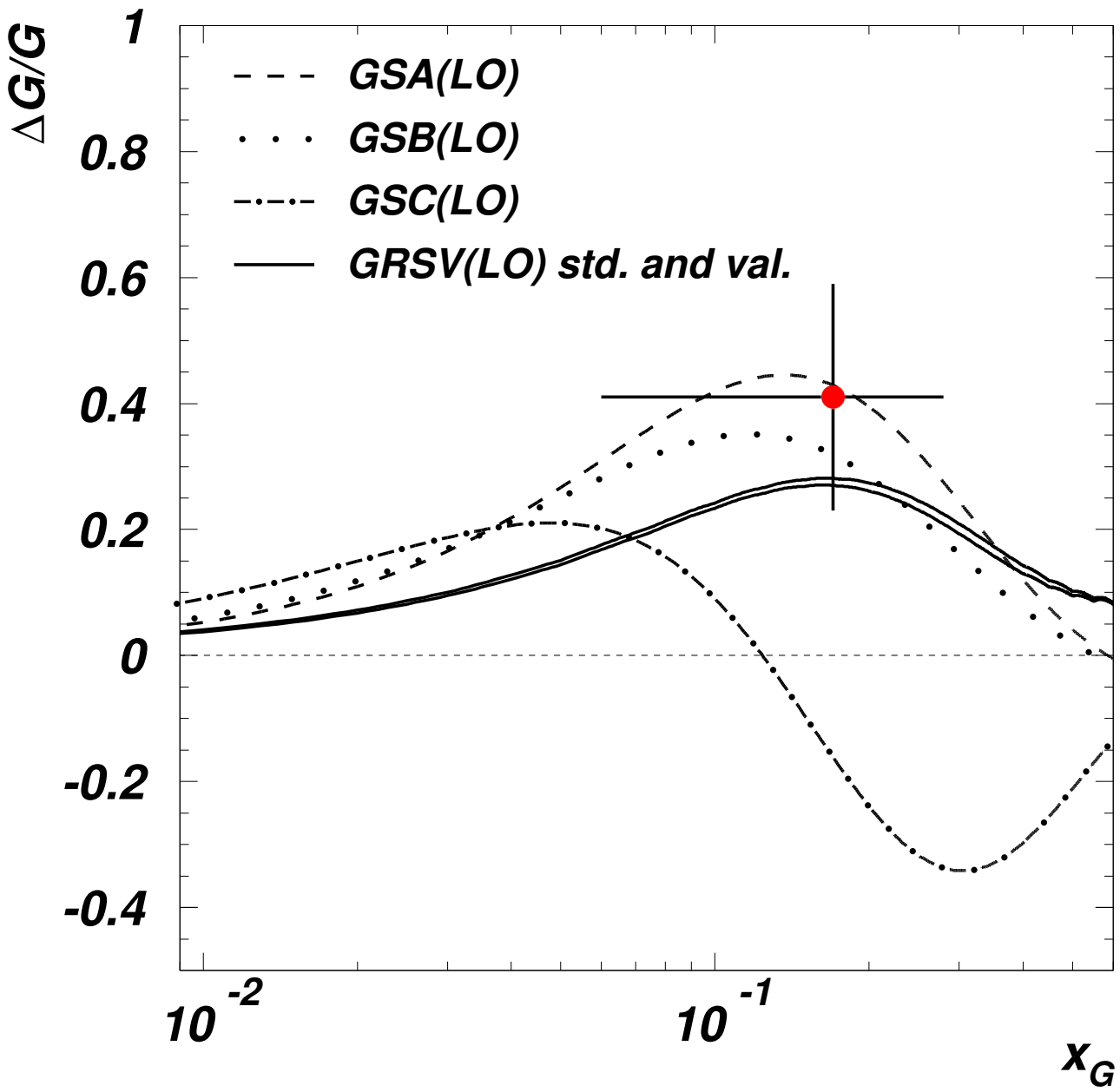
at $\langle x_G \rangle = 0.17$ and $\langle \hat{p}_T^2 \rangle = 2.1\ \text{GeV}^2$



Note: possible missing contributions.

If missing cross section is dilution, significance doesn't change.

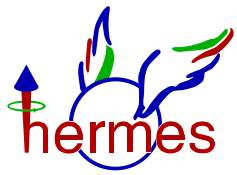
Comparison to LO QCD Fits



Vertical error bar on $\Delta G/G$ is stat. + exp. syst. uncertainties.
Horizontal error bar indicates range of x_G probed.

Fits have been evolved to the scale $\hat{p}_T^2 = 2$ (GeV/c)^2.

Conclusion



- Negative asymmetry at high p_T in photoproduction:

$$A_{||} = -0.28 \pm 0.12\ (\mathrm{stat.}) \pm 0.02\ (\mathrm{syst.})$$

  for h^+h^- pairs with $p_T^{h1} > 1.5$ GeV/c and $p_T^{h2} > 1.0$ GeV/c.

- Shape of cross-section in reasonably good agreement with PYTHIA model, but factor of two low.

- With stated assumptions,

$$\Delta G/G = 0.41 \pm 0.18\ (\mathrm{stat.}) \pm 0.03\ (\mathrm{exp.\ syst.})$$

  at $\langle x_G \rangle = 0.17$ and scale $\langle \hat{p}_T^2 \rangle = 2.1$ GeV^2.

- This is a LO QCD direct (+ soft VMD) model. Possible contributions from e.g. hadronic structure of photon, NLO corrections, etc. have been ignored. If missing contributions are dilutions, significance of result does not change.

- Future HERMES measurements will improve statistical uncertainty by roughly a factor $\sqrt{2}$ by May 2000.